E706 CRYOSYSTEM DESIGN NOTE

E706EN022

TITLE: Sizing of Separate Exit Piping for Each Relief Device at

Full Fire Condition

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OBJECTIVE OF NOTE:

To determine the required flow capacity, available flow capacity, diameter and composition of the vent line.

REVIEWED BY:

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Name   Date   Project Manager   Date

CALCULATIONS AND DISCUSSION:

Determination of flow rate (required capacity):

Reference-Compressed Gas Association S-1.3-1980
Pressure Relief Device Standards
Paragraph 5.3.3

$$Q_A = G_u A^{0.82}. \text{ (Flow capacity in cubic feet per minute of free air.)}$$

$$G_u = \frac{633,000}{LC}\sqrt{\frac{ZT}{M}}. \quad \text{Gas factor for uninsulated containers.}$$

A = $1641 ft^2$. (Overall length + 0.3 outside dia.) × (outside dia.) × (3.1416). Total outside area of the container in square feet.

Z = 1.0. Compressibility factor at flowing conditions.

P = $(16)(1.21) + 14.7 = 34.06 psia$. Maximum allowable vessel pressure during venting due to a fire.

T = $173.23°R$. Temperature of lading at pressure (P) at flowing conditions.

M = 40. Molecular weight of argon.

C = 377. Constant for gas related to ratio of specific heats.

L = $66.27 BTU/lb$. Latent heat at flowing conditions.

overall length = 25.625 ft.

outside dia. = 17.0 ft.

$\therefore Q_A$ = 22,827 SCFM of air.

Determination of available flow capacity, assuming no inlet or exit pressure drops:

B.S. and B Rupture Disk

$$Q_{RD} = \frac{260AP}{\sqrt{SP.GR(T)}}. \text{ From BS and B Catalogue.}$$

A = $28.3in^2$. Area of rupture disk.

P_1 = $34.06psia$. Flowing inlet pressure.

$SP.GR$ = 1. Specific gravity of air.

T = $520°R$. Flowing temperature.

$\therefore Q_{RD}$ = $10,990 SCFM$ of free air.

Anderson Greenwood Relief Valve:

$$Q_{RV} = \frac{6.32ACKP_1}{\sqrt{MTZ}}. \text{ From Anderson Greenwood catalogue.}$$

A = $19.56in^2$ orifice area of a $6'' \times 8''$ 93T relief valve.

C = 356. Gas constant based on ratio of specific heats for air.

K = 0.845. Certified Nozzle Coefficient.

P_1 = $34.06psia$. Flowing inlet pressure.

M = 29. Molecular weight of air.

T = $520°R$. Flowing temperature.

Z = 1. Gas compressibility factor.

$\therefore Q_{RV}$ = $10,300 SCFM$ of free air.

Total available relief capacity:

$$Q_{TOT} = Q_{RD} + Q_{RV}.$$
$$= (10,990) + (10,300) = 21,290 SCFM \text{ of free air.}$$

Exit pressure drop for full fire condition:

Assumptions:

1. The temperature of the gas exiting the relief devices is at saturation conditions.

2. The flow is incompressible, mach number less than 0.3.

3. Inertial effects are ignored.

4. Initial effect of a warm slug of argon gas is ignored.

5. All pressure drop parameters, variables, are based on the average exit temperature and average exit pressure.

6. Twenty-four lb/sec will be used as the mass flow rate, as determined in E706 Design Note Number 12.

7. Worst case Nusselt number is calculated from the following equation, $Nu = 0.022(Re)^{0.8}(Pr)^{0.6}$.

   Note: The heat flux calculated using the Dittus-Boelter equation given in Assumption 7 is the worst that can occur. This heat flux can only last for a short time, on the order of a half a minute. As the vent line cools, the heat flux will decrease rapidly to a value of about $575 BTU/hr\ ft^2$ (Barron).

Determination of pressure in exit vent line:

Table 1 shows how the pressure drop varies with diameter for the following tentative exit vent line. The exit vent line has a 32 foot straight run, then a 90° elbow which points upward, and attached to the elbow is a three-foot section of straight line. The calculations do not take into account the expander, which

would be required to be attached to the vent line to either of the two relief devices.

CONCLUSIONS:

1. The two present relief devices do not provide adequate capacity, as required by the Compressed Gas Association.

   Capacity required 22,837 SCFM Air > capacity available 21,290 SCFM Air.

2. The pressure drop due to the exit vent line varies from $3.71 psi$ to $0.21 psi$, as the vent line diameter varies from 8 inch *sch* 10 pipe to 16 inch *sch* 10 pipe.

3. Table I shows that, when the expandor pressure drop is added to the exit vent line pressure drop, none of the listed vent line diameters will meet the $1 psi$ maximum pressure drop, as required by E706 Design Note Number 12.

TABLE I PRESSURE DROP VS. PIPE DIAMETER

	COMPONENT	I.D. FT / O.D. FT	LENGTH FT	FRICTION FACTOR	K	$h\left[\frac{BTU}{FT^2-HR^\circ R}\right]$	A_T (FT²)	ΔT °R	TOTAL HEAT INPUT BTU/HR [W]	$\dot{m}$ LB/SEC
8 IPS SCH 10	STRAIGHT LINE	0.694	35	0.0140	0.706	40.4	91	347	3.74×10^8 [W] / 1.276×10^6 [BTU/HR]	24.0
	ELBOW			0.0140	0.420					
	EXIT	0.719			1.0					
10 IPS SCH 10	STRAIGHT LINE	0.874	35	0.0135	0.541	26.7	113	347	3.07×10^5 / 1.048×10^6	24.0
	ELBOW				0.405					
	EXIT	0.896			1.0					
12 IPS SCH 10	STRAIGHT LINE	1.033	35	0.0130	0.440	19.8	134	347	2.697×10^5 / 9.207×10^5	24.0
	ELBOW				0.390					
	EXIT	1.063			1.0					
14 IPS SCH 10	STRAIGHT LINE	1.141	35	0.0125	0.383	16.6	147	347	2.48×10^5 / 8.44×10^5	24.0
	ELBOW				0.375					
	EXIT	1.167			1.0					
16 IPS SCH 10	STRAIGHT LINE	1.302	35	0.0121	0.325	13.0	168	347	2.22×10^5 / 7.60×10^5	24.0
	ELBOW				0.363					
	EXIT	1.333			1.0					

TABLE I CONT.

ΔH	EXIT TEMP.	AVG. TEMP °R	DENSITY AVG. LBS/FT³	VELOCITY AVG. FT/SEC	PRESSURE DROP [PSI]	REYNOLDS NUMBER AVG.	MACH NUMBER	EXPANDER PRESSURE DROP PSI	TOTAL PRESSURE DROP (PSI)
8 — P S 34.4 J/g 1374 J/MOLE	152 °K 274 °R	124 °K 224 °R	0.249	255	3.71	6.42 × 10⁶	0.376		
10 — P S 28.2 J/g 1127 J/MOLE	140 °K 252 °R	118 °K 213 °R	0.261	153	1.28	5.20 × 10⁶	0.232		
12 — P S 24.8 J/g 991 J/MOLE	134 °K 241 °R	115 °K 207 °R	0.269	106	0.60	4.68 × 10⁶	0.163	0.50	1.10
14 — P S 22.8 J/g 912 J/MOLE	130 °K 234 °R	113 °K 204 °R	0.274	86	0.38	4.28 × 10⁶	0.133	0.81	1.19
16 — P S 20.4 J/g 816 J/MOLE	126 °K 227 °R	111 °K 200 °R	0.279	65	0.21	3.83 × 10⁶	0.102	1.09	1.30